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## **A New Illusion at Your Elbow**

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**Abstract:** On experiencing distal-proximal tactile motion on the volar side of the forearm starting at the wrist, subjects significantly anticipate touch of the elbow crook. This illusion, popular as a children's game, was quantified in ninety participants (forty-seven women) on both arms. As a top-down explanation of the illusion, we discuss a model of Bayesian inferences. As a bottom-up contribution, we consider afterdischarges of cortical neurons, which receive input from skin mechanoreceptors specifically driven by slow-motion tactile stimuli. Like previously described illusions, the elbow crook illusion is larger on the nondominant arm. Women showed a smaller illusion than men, giving testimony to their reportedly superior cutaneous sensitivity.

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## **A new illusion at your elbow**

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### **Abstract**

On experiencing distal-proximal tactile motion on the volar side of the forearm starting at the wrist, subjects significantly anticipate touch of the elbow crook. This illusion, popular as a children's game, was quantified in 90 participants (47 women) on both arms. The illusion is explained by afterdischarges of those S1 neurons, which receive input from skin mechanoreceptors specifically driven by slow-motion (<5cm/s) tactile stimuli. As previously described illusions, it is larger on the nondominant arm. Women showed a smaller illusion than men, giving testimony to their reportedly superior cutaneous sensitivity.

Among the manifold illusions of the cutaneous sense (Lederman and Jones, 2011), some are not readily amenable to playful experimentation as they require substantial technical equipment (Hayward, 2008). One exception is a game, Swiss children typically enjoy on playgrounds. They stimulate the inner side of a friend's forearm by slowly moving a finger from the wrist towards the crook of the elbow. Eyes closed, the friend has to shout "stop!" on feeling the crook being reached. On opening the eyes, there is much amazement about an anticipation error, frequently in the order of several centimeters. We investigated the crook-of-the-elbow illusion under controlled conditions (Fig. 1) and suggest a neurophysiological explanation of its origin.

\*\*\*\*\* INSERT FIG. 1 ABOUT HERE \*\*\*\*\*

Our measurements confirm a powerful and robust illusory anticipation of touch at the elbow crook when the tactile stimulus is slowly moved in a proximal direction starting at the wrist. In other words, the track on the skin appears subjectively enlarged. This is in contrast to most previously described cutaneous motion illusions that consist in a subjective length *contraction*. These have been accounted for by a model of Bayesian inference (Goldreich, 2007), which views the most probable cutaneous percept as "a compromise between imprecise sensorineural information and the observer's expectation of slow movement" (Goldreich, 2007, p. 2), arguing that, under natural circumstances, object motion on the skin is slow. In the case of movements faster than those encountered in natural scenarios, as applied in many laboratory situations, Bayesian slow-motion priors would be violated and thus give rise to an illusory length contraction. The cutaneous motion illusion studied here occurs in response to a stimulation velocity at or even below the velocities typically experienced in everyday life (e.g. during caressing movements or the crawling of an insect) and a participant's expectations of a

low speed of tactile motion are not violated. Top-down effects of expectation on perceptual experience are thus unlikely the source of the elbow-crook illusion. Instead, an explanation may be found in the characteristics of skin mechanoreceptors and the S1 neurons they project to. C and A $\delta$  fibers innervating mechanoreceptors are prominently driven by slow moving (< 5cm/s) stimuli, and the corresponding neurons in S1 are known for their exceptionally long afterdischarges (Whitsel et al., 1986; McKenna et al., 1984). These afterdischarges were made responsible for the subjective enlargement of cutaneous motion tracks applied at velocities below 5cm/s (Whitsel et al., 1986). These authors had their subjects indicate the offset point of a tactile motion on the dorsal aspect of the forearm and found a subjective overshooting at velocities below 5cm/s, but an increasing undershooting with increasing stimulation velocities (between 25cm/s and 250cm/s). The displacement of the endpoint of a slow-motion track on the skin in the direction of movement may be equivalent to the error of anticipating a body landmark in the case of a continuing motion. The fact that, in the subset of participants stimulated in a proximo-distal direction, the anticipation error was only small may be accounted for by a proximal-distal gradient of increasing tactile sensitivity (Weinstein, 1968) and a locognosic acuity which is especially pronounced around the wrist (Cody et al., 2008). The observation that men showed a stronger illusion than women corroborates previous findings of a better cutaneous sensitivity in female compared to male participants (Weinstein, 1968; Chen et al., 1995; Peters et al., 2009). The laterality effect, i.e. the larger illusory anticipation on the *left* forearm, was unexpected, as for stationary stimuli, no marked side differences in tactile sensitivity are apparent (Weinstein, 1968). It is in line, however, with a stronger multisensory (visual-tactile-proprioceptive) illusion on the nondominant compared to the dominant hand after dynamic tactile stimulation (slow-motion brushing; Ocklenburg et al., 2011). The more pronounced arm differences in men compared to women may reflect their stronger functional cerebral hemispheric laterality (McGlone, 1980) and the absence of modulating effects of the menstrual cycle (Hausmann, 2005).

Explaining the mechanisms of an illusion should never aim at diminishing our amazement on experiencing it. In this sense, the surprise by the little playground game investigated here will hopefully remain at your elbow.

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#### FIGURE CAPTION

LEFT: Participant's arm was stretched out and stimulated on the volar side with a blunt stylus moving from the wrist towards the elbow's crook. A constant speed of approx. 2 to 3 cm/s had been practiced beforehand, and the constant soft pressure was determined by the stylus' weight (5g). Skin stretching was carefully avoided. Eyes closed, the participant had to indicate verbally once touch was experienced in the crook. The deviation, measured to the nearest mm, could not be observed by the participant.

RIGHT: 47 women and 43 men gave written informed consent to participate in the experiment approved by the ethics committee of the university of Basel. They were all right-handed and of comparable age (mean=41.9 yrs., SD=16.4 yrs.). Participants were tested on both left and right arm (counterbalanced order). Overall, the anticipation error was significant (mean=3.0cm, SD=2.2cm;  $t=14.1$ ,  $df=89$ ,  $p<.0001$ ). ANOVA revealed a main effect of sex ( $F(1,88)=6.7$ ,  $p=.011$  and arm ( $F(1,88)=11.0$ ,  $p=.001$ ). Women showed a smaller error than men, and the illusion was larger on the left than the right forearm. The interaction also reached significance ( $F(1,88)=4.3$ ,  $p=.042$ ); the arm difference being larger in men than in women.

Fifty-eight of the participants (31 women) were also tested in a proximo-distal direction, having to indicate when the moving stimulus approaching from the elbow crook seemed to have reached the wrist. The illusory anticipation of the wrist (mean=1.4cm, SD=1.0cm) was significantly smaller than that on the elbow ( $t=5.8$ ,  $df=57$ ,  $p<.0001$ ; data not shown).

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FIGURE 1:

